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Summary of Research Report on NASA Grant NAG-1-1681

STRUCTURAL ACOUSTIC CHARACTERISTICS OF AIRCRAFT AND ACTIVE CONTROL OF INTERIOR NOISE

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INTRODUCTION

The reduction of aircraft cabin sound levels to acceptable values still remains a topic of much research. The use of conventional passive approaches has been extensively studied and implemented. However performance limits of these techniques have been reached. In this project, new techniques for understanding the structural acoustic behavior of aircraft fuselages and the use of this knowledge in developing advanced new control approaches are investigated. A central feature of the project is the Aircraft Fuselage Test Facility at Va Tech which is based around a full scale Cessna Citation III fuselage. The work is divided into two main parts; the first part investigates the use of an inverse technique for identifying dominant fuselage vibrations. The second part studies the development and implementation of active and active-passive techniques for controlling aircraft interior noise.

SIGNIFIGANT PROJECT ACHIEVEMENTS

The significant achievements of each of the project sections are summarized in bullet fashion below.

A. *INTERIOR NOISE DIAGNOSTICS*

(1) An inverse system identification procedure for interior noise

- Testing of the inverse identification technique on the Cessna fuselage was completed. Three frequencies encompassing the types of expected disturbances and responses were investigated. The results clearly demonstrated the efficiency and ability of the technique to identify small scale fuselage vibrations that were coupled to the interior noise fields.
- A SVD approach was developed to break the measured vibrations down into important orthogonal components. The results showed that only the first two or three SV's were needed.
- An optimal technique based upon the Genetic Algorithm(GA) was developed for optimally locating piezoelectric structural actuators to drive the important SV's.
- The GA approach was used to find the best locations of the actuators (four) for three test frequencies.
- The inverse approach was tested on the fuselage rig with a realistic engine disturbance. The results demonstrated that the inverse technique will work on real systems.

B. *ACTIVE CONTROL OF INTERIOR NOISE*

(1) ASAC experiments on interior noise reduction using piezoelectric actuators.

- An ASAC approach was implemented and tested on the fuselage using the optimally located actuators obtained in Section A. The results demonstrated that the use of the optimal design technique led to global control at all three test frequencies which is a large improvement over previous testing using heuristic approaches.

- The ASAC testing also demonstrated that the especially constructed, curved piezoelectric ceramic actuators had enough control authority at reasonable control voltage levels(approx. 30-60V RMS) to control realistic interior noise levels.
- The ASAC system was tested with a realistic engine disturbance and the results demonstrated that ASAC will work in realistic aircraft systems.

(2) Active trim panels for interior noise reduction

- The fuselage experimental rig was modified to implement three exterior uncorrealated noise sources.
- Further experiments were performed using the active trim panels with multiple structural reference sensors and improved filters (lower latency). The results demonstrated global reductions of broadband sound over a reasonable head height region. The work confirms that it is possible to use feedforward control of broadband fuselage radiated sound as long as the control path latency is low. The work also confirms the potential of using active trim panels to control interior noise.
- Different forms of structural reference sensors and filtering were investigated. It was found that fuselage mounted accelerometers passed through single pole filters provided the best all round sensing approach.

(3) Advanced LMS controller development

- Interface software for the TMS Quad 4, C40 board was developed, implemented and successfully tested.
- A Labview interface was developed, implemented and successfully tested. The interface allows real time monitoring and adjustment of control parameters.
- New control software which allowed de-coupling of the LMS controller as well as multiple reference signals was written, implemented and successfully tested.

C. ACTIVE-PASSIVE CONTROL OF INTERIOR NOISE

(1) Use of adaptive TVA's for interior noise reduction.

- Electromechanical TVA's with high Q's ,based upon a supported stepping motor were developed and successfully tested.
- An analytical model for a plate with multiple TVA's including sound radiation was developed.
- Algorithms for global detuning of multiple TVA's to minimize a related cost were developed.
- The use of the TVA's in a tuned and globally de-tuned form for controlling sound radiation from plates was experimentally and analytically investigated. It was shown that global detuning leads to increased sound control.
- Preliminary work on the development of a solid state piezoelectric TVA was completed. Local feedback control laws for tuning the TVA were developed and tested on SDOF systems. The results show that the solid state tuning hardware and method has high potential.
- Experiments on using electromechanical ATVA's implemented on the Cessna fuselage were carried out. The results confirmed that globally detuned TVA's lead to increased sound reduction in realistic, complex structures.

(2) Smart acoustic foam for boundary layer noise interior noise reduction.

- Advanced smart foam elements with improved low frequency performance were developed and tested. The new elements used lighter glue and had attachments for the PVDF edges to increase out of plane motion.
- Further experiments on using multiple smart foam elements and structural reference sensors to control panel radiation were carried out. The results confirmed the ability to control sound radiation from complex panel motions and the use of realistic structural reference sensors in a feedforward control approach.
- Preliminary design and construction of a suitable wind tunnel test rig at Va Tech was completed. A suitable panel, based upon NASA specifications was constructed and its dynamics tested. Various mounting techniques were studied and a suitable wind tunnel/panel test section was constructed and tested. Various noise problems in the wind tunnel were identified.

CONCLUSION

Much progress was made in this period of work. New inverse techniques for identifying important low level structural motions were demonstrated. Optimal ASAC design methods were established. Both fully active and hybrid active-passive methods for reducing interior noise in realistic fuselage structures were successfully demonstrated.